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CITY OF BOSTON AIR POLLUTION CONTROL COMMISSION
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DAVID STANDLEY,
Executive Director

CONTROL OF SULFUR OXIDES

Report of the Executive Director

to the

CITY OF BOSTON AIR POLLUTION CONTROL COMMISSION

1969

Commissioners:
James A. Fay, Chairman — Andrew P. Sackett, M. D., Commissioner of Health & Hospitals — Edward V. Hickey

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INTRODUCTION

The Boston Air Pollution Control Commission has expressed a desire to proceed as rapidly as possible to reduce air contaminant levels in the air over Boston. The Commission has suggested that existing levels may be deleterious to the health and welfare of the City's population. The public, both directly and through its representatives, has expressed dissatisfaction with the quality of Boston's air. The Commission believes that future increases in activity within the City and the metropolitan area will worsen air quality, unless effective government action is taken.

It recognizes that available evidence of the adverse health effects of existing air contaminant levels may not convince all parties of the pressing need for control of emissions. It also recognizes that, in all probability, no one air contaminant is alone responsible for the impacts of urban air pollution upon respiratory health which have been observed in many urban areas and postulated in others. The Commission nevertheless has suggested that the oxides of sulfur are an important class of air contaminants. The use of low-sulfur fuels is a control technique that may be relatively uncomplicated and not unduly burdensome, and which may be readily and promptly available to effect a substantial improvement in air quality. A need to similarly reduce levels of other classes of air contaminants is recognized, and a general commitment to do so is stated.

I have therefore prepared, for the benefit of the Commission, a condensed statement of the problem of air contamination by sulfur oxides and the matters of control and regulation of emissions of sulfur oxides (principally sulfur dioxide) accompanied by my recommendations.

David Standley

David Standley
Executive Director

THE PROBLEM OF AIR POLLUTION BY SULFUR OXIDES

THE EFFECTS

The effects of sulfur oxides on human and animal physiology, on materials, and on visibility are discussed in the publication Air Quality Criteria for Sulfur Oxides, January 1969, prepared and published by the United States Department of Health, Education, and Welfare (DHEW), in accordance with the Federal Air Quality Act of 1967. It is the most recent and the most detailed discussion of the subject. This document, a companion document on suspended particulate matter, and summaries, are available.

The essence of these documents is that the critical effects of urban air pollution are the acute and chronic impairment of respiratory function. The most susceptible receptor populations are the elderly, the infirm, and the very young. It is pointed out that these effects are likely not due to sulfur dioxide alone.

ACUTE HEALTH EFFECTS

Observed acute effects associated with "disasters" - Meuse Valley, Donora, New York, London - are apparently related to sharp increases in levels of air contaminants including sulfur dioxide and suspended particulates, in association with high humidity and low ambient temperature, which persist for several days.

> Analyses of numerous epidemiological studies clearly indicate an association between air pollution, as measured by sulfur dioxide, accompanied by particulate matter, and health effects of varying severity. This association is most firm for the short-term air pollution episodes. (Emphasis added) (1).

In its criteria documents on sulfur oxides and particulates, the DHEW has suggested levels of those contaminants which should not be exceeded in short-time or acute exposure periods (not to be regarded as assuredly safe levels).

Dr. Harry Heimann, M.D.*, while at Harvard School of Public Health, performed a preliminary study ** of the effects in the Boston area of two episodes occurring in the fall of 1966. The first episode was a two-day period of elevated contamination levels in late October. The second, more severe degradation of air quality was the oft-cited "Thanksgiving Week Incident" which involved most of the eastern seaboard for three to four days. While the episodes were not the most severe the area has ever suffered, they were fairly typical of the region. We expect only about one such episode per year. Dr. Heimann used air quality data from the Air Quality Study of the Metropolitan Air Pollution Control District and Vicinity (Massachusetts Department of Public Health), then already in progress.

From a preliminary listing of all possible indicators of adverse effects of these episodes on human health, he found five indicators, records of which were reasonably available to him.

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* Dr. Heimann, formerly Director of the Division of Occupational Hygiene, U.S. Public Health Service, is now with the Department of Community Medicine, Mount Sinai School of Medicine, New York City.

** A draft report of this study has been made available to me, and the following comments are based on that draft.

These were:

1. (a). crude total mortality rates from official death records,

   (b). death rates attributed to respiratory or heart disease as primary or contributory cause,

2. records of a group of elderly, resident in nursing homes, which he also used to assess temporal or spatial differences in worsening conditions,

3. records of deaths of foetuses of women pregnant during these episodes,

4. records of patients attending clinics for chronic, non-specific respiratory disease, and

5. records of visits to the emergency room of a major local hospital.

A considerable increase in the number of visits to clinics by a group of out-patients with chronic non-specific respiratory disease was shown to be associated with both of these episodes.

This is the only study of this nature conducted in the Boston area. It was necessarily limited, and most attention was focused upon mortality (three of five indices). Not studied (presumably due to lack of staff and time, and limited availability of records) were the potentially very important records of school and industrial absenteeism-sickness and the conditions of persons suffering from bronchial asthma, emphysema, or other chronic obstructive pulmonary disease (except noted by clinic and emergency room visits). One of the two morbidity indices examined showed a "positive" or undesirable effect associated with both episodes. The results of Dr. Heimann's preliminary study seem to me to dispel complacency about the quality of Boston's air, if and where complacency exists.

CHRONIC HEALTH EFFECTS

The effects of chronic exposure to community air pollution on respiratory function, as such pollution is indicated by sulfur dioxide or suspended particulate levels, are less clear. The effect of smoking on health largely obscures any effects of air pollution, within the "levels of ignorance" (uncertainties) which have existed in epidemiological studies. However, there seems to be a supportable consensus that there is an increase in morbidity and mortality from impairment of respiratory function associated with chronic exposure to urban air pollution. Whether such effects are wholly due to sulfur dioxide is subject to sharp debate. Some authorities contend that we do not yet have sufficient information to establish either the nature of air contamination or the degree of exposure necessary to produce such harmful effects. The majority opinion at present is that oxides of sulfur, likely in their higher oxidation states, such as sulfur trioxide (SO_3) and sulfates (SO_4), are directly involved, but necessarily in association with suspended particulate matter.

> The association between long-term community exposure to air pollution and respiratory disease incidence and prevalence rates is conservatively believed to be intermediate in its reliability. Because of the reinforcing nature of the studies conducted to date, the conclusions to be drawn from this type of study can be characterized as probable.
>
> The association between long-term residence in a polluted area and chronic disease morbidity and mortality is somewhat conjectural. However, in the absence of other explanations, the findings of increased morbidity and of increased death rates for selected causes, independent of economic status must still be considered consequential. (2)

Dr. Frank Speizer (Harvard Medical School, Boston City Hospital) states, in part, in the summary of a recent paper:

> Smoke or suspended particulate matter and sulfur dioxide as measures of general pollution in the air have been correlated with the occurrence of respiratory diseases after standardization for smoking habits, age, social class, and occupation...In terms of chronic effects from exposure to smoke or suspended particulates and sulfur dioxide, the constancy of the results in many studies is suggestive of important associations between chronic exposure and morbidity and mortality from chronic respiratory diseases. We do not know how this exposure exerts its effect...(Emphasis added) (3).

BOSTON AIR QUALITY AND HEALTH EFFECTS

In the downtown section of Boston Proper, in 1966, the annual mean concentration of sulfur dioxide was about 170 $\mu g/M^3$ (.06 ppm). During the fall episodes mentioned previously, the mean concentration of sulfur dioxide exceeded 400 $\mu g/M^3$ (.14ppm). These values exceed those minimum concentrations of sulfur dioxide cited by DHEW as associated with adverse health effects.

> Under the conditions* prevailing in areas where the studies were conducted, adverse health effects were noted when the 24-hour average level of sulfur dioxide exceeded 300 $\mu g/M^3$ for three to four days, and when the annual mean level of sulfur dioxide exceeded 115 $\mu g/M^3$. (4).

TABLE 1

Condition	Annual Mean Concentration		Maximum 3-day average Concentration	
	($\mu g/M^3$)	(ppm)	($\mu g M^3$)	(ppm)
Observed Air Quality in Central Boston - 1966	170	.06	460	.16
USDHEW "adverse health effects" level	115	.04	300	.11

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* These conditions include relatively high particulate levels, and could include socio-economic factors.

The evidence regarding health effects indicates that adverse reactions are associated with the concurrent existence of elevated levels of sulfur oxides and of suspended particulate matter. In the downtown section of Boston, in 1966, the annual mean concentration of total suspended particulate matter was about 100$\mu g/M^3$; during the Thanksgiving episode, the 5-day mean concentration was 185$\mu g/M^3$. The information presented in the DHEW "criteria" document on sulfur oxides and particulates* indicates that these concurrent concentrations of contaminants, over the time periods indicated, ought to be regarded as deleterious to the public health, and indicative of probable increased morbidity due to air pollution.

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* Interpretation of the data selected by DHEW for presentation in its "criteria" documents should be undertaken with an awareness that British and European air sampling and analytical techniques differ from United States techniques. The numerical values reported for concentrations of suspended particulate matter cannot be compared. The U.S. techniques appear to result in much lower numerical values for comparable concentrations.

REFERENCES

(1). United States Department of Health, Education, and Welfare, Air Quality Criteria for Sulfur Oxides, page 10:19.

(2). U.S.D.H.E.W., op. cit., page 10:20

(3). Dr. Frank Speizer, M.D.,"An Epidemiological Appraisal of the Health Effects of Ambient Air: Particulates and Oxides of Sulfur," Paper #69-69, page 9.

(4). U.S.D.H.E.W., op. cit., pages 10:22, 10:21, and 10:22.

THE PROBLEM OF AIR POLLUTION BY SULFUR OXIDES

THE SOURCES OF SULFUR OXIDES

Sulfur oxides in the air over the Boston metropolitan area result almost entirely from the burning of sulfur-containing fuels. Approximately ninety percent of the emissions are from the combustion of medium (#5) and heavy (#6) residual oils. Fuel use and sulfur dioxide emission estimates are summarized in Tables 1 and 2. The geographic areas for which estimates are made are:

1. the City of Boston,
2. the area of the cities and towns lying wholly, or largely within ten miles of the State House, and
3. the Boston Standard Metropolitan Statistical Area, (S.M.S.A.).

In addition, estimates are made for facilities of the City of Boston.

Within the City of Boston, consumption of fuel for space heating results in about 45% of the total sulfur dioxide emissions. The Boston Edison Company and the Massachusetts Bay Transit Authority are estimated to discharge, in total, another 45% of total sulfur dioxide emissions. Industrial consumption for process and power contributes the remainder. Within the larger area lying within about ten miles of the State House, space heating usage and utility (Edison and others) consumption each account for about 42% of total sulfur dioxide emissions. All but one of the utility plants in the S.M.S.A. are located within this second area (Salem Harbor Station of New England Electric Company is the exception). Thus, only a small percentage of the total sulfur dioxide emissions throughout the rest of the S.M.S.A. are attributable to public utilities.

Sulfur dioxide emission estimates for City of Boston facilities are shown, by department, in Table 3. Further breakdowns are presented in the Appendix.

It is obvious that the City of Boston's contribution to sulfur dioxide levels in Boston is minor. City facilities contribute only about seven percent of the estimated total sulfur dioxide emissions within the City; about two percent within the S.M.S.A. Nevertheless, the City, in its proper role of leadership, is expected to meet or exceed both the degree of emission reduction and the timetable imposed on others.

TABLE 1

Annual FUEL USE AND SULFUR DIOXIDE EMISSIONS Estimate

Stationary Sources in the Boston Area

ITEM	AREA	FUEL			TOTAL
		Oil*	Coal	Natural Gas	
		(10^6 bbl)	(10^3 ton)	(MMCF)	
AMOUNTS OF FUELS USED	City of Boston:				
	City buildings (a)	1.0	9.4	Negligible	
	All sources (b)	24	?	14,400	
	Ten-mile radius: (b)	64	?	45,000	
	S.M.S.A.: (b)	88	200	60,000	
		(10[illegible] BTU)	(10[illegible] BTU)	(10[illegible] BTU)	(10[illegible] BTU)
ENERGY EQUIVALENT (10[illegible] BTU)	City of Boston:				
	City buildings	6.2	0.2	Negligible	6.4
	All sources	160	?	14.4	170
	Ten-mile radius:	400	?	45	450
	S.M.S.A.:	540	6	60	610
		(10[illegible] tons)	(10[illegible] tons)	(10[illegible] tons)	(10[illegible] Tons)
RESULTING SO_2 EMISSIONS (10[illegible] Tons)	City of Boston:				
	City buildings	7	Negligible	Negligible	7
	All sources	120	?	Negligible	120
	Ten-mile radius:	300	?	Negligible	300
	S.M.S.A.:	380	10	Negligible	390

* All grades

(a) "Control of Sulfur Oxides", Report of the Executive Director to the City of Boston Air Pollution Control Commission, July 24th, 1969.

(b) Air Pollution Emission Survey for the Boston SMSA, U.S. Department of Health, Education, and Welfare, August, 1968.

TABLE 2

Annual FUEL USE AND SULFUR DIOXIDE EMISSIONS Estimate

Stationary Sources in the Boston Area

FUEL OIL ONLY

ITEM	AREA	USAGE				TOTAL
		Space Heating		Process & Power		
		Domestic[1]	Other[2]	Industry[3]	Utility[4]	
AMOUNTS OF FUELS USED (10^6 bbls.)	City of Boston:					
	City buildings	-	1.0	-	-	1 x10^6 bbl.
	All sources	8.9	7.2	2.0	7.0	24 "
	10-mile radius:	24.0	17.0	5.6	17.0	64 "
	S.M.S.A.:	37	26	8.4[5]	17.0	88 "
ENERGY EQUIVALENT (10^{12} BTU)	City of Boston:					
	City buildings	-	6.2	-	-	6 x 10^{12} BTU
	All sources	52	49	13	44	160 "
	10-mile radius:	140	110	35	110	400 "
	S.M.S.A.:	220	160	53	110	540 "
RESULTING SO_2 EMISSIONS (10^3 tons)	City of Boston:					
	City buildings	-	7	-	-	7 x 10^3 tons
	All sources	6.2	48	15	52	120 "
	10-mile radius:	17	110	42	130	300 "
	S.M.S.A.:	26	170	55	130	380 "

[1] #2 oil @ 0.25% sulfur

[2] #5/#6 oil - #5 oil @ 1.6% sulfur, #6 @ 2.2% sulfur - 2.0% average

[3] #6 oil @ 2.2% sulfur

[4] #6 oil @ 2.5% sulfur

[5] Including 1.1 x 10^6 barrels #2 oil

Information from same sources as for Table 1.

TABLE 3

SULFUR DIOXIDE EMISSIONS

CITY OF BOSTON SOURCES, BY DEPARTMENT

A SUMMARY

DEPARTMENT		EMISSIONS OF SULFUR DIOXIDE (tons per year)
Boston Housing Authority		3,300
Boston School Department		1,360
Department of Health & Hospitals		1,100
Penal Division - Deer Island		440
Parks & Recreation Department		250
Fire Department		50
Other (Estimated)		500
	TOTAL	7,000

CONTROL OF SULFUR OXIDES

Sulfur oxide concentrations at ground-level may be reduced by reducing emissions or by improving dispersion of effluents, or both. Reduction of emissions may be accomplished by utilizing a different fuel which is inherently of lower sulfur oxide emission potential. Reduction of emissions may also be accomplished by incorporating devices or systems to remove sulfur oxides from the effluent gas prior to release. It has been proposed that ground-level concentrations of these contaminants may be controlled by use of tall stacks to increase dispersion, or by scheduling fuel use to take advantage of favorable meteorological conditions.

Use of low-sulfur fuels is the only technique that would be generally effective in Boston. Sulfur dioxide emission control systems are being developed for larger fuel-burning sources, and their potential availability should be recognized in the drafting of any regulation, even though none are currently practicable. Emission controls are available for many types of non-fuel sources of sulfur dioxide, but no such sources are known to exist in the City. Really tall stacks will likely never be built this close to Logan Airport. The value of "meteorological controls" is presently uncertain, for any source.

Therefore, I will discuss only the first approach - reduction of emission potential. This technique is applicable to the fuel-burning category of sulfur oxide sources. Included as possible alternate energy sources are nuclear power, electricity from external sources, "central steam", heat generated by and recovered from refuse disposal operations, and the substitution of low-sulfur fuels such as low-sulfur residual oil, distillate oil, and natural gas. The substitution of some combination of natural gas and distillate oil (a "dual-fuel" system) for high-sulfur coal or residual oil is possible, as is the occasional temporary substitution of low-sulfur for high-sulfur coal or residual oil. A brief discussion of each alternative follows.

NUCLEAR ENERGY:

Nuclear energy is currently feasible only for heat production at large facilities located outside of metropolitan complexes, and therefore, is only a possible source of energy for external generation of electric power. To the extent that such electrical power would be used for space heating, a reduction in sulfur dioxide emissions would be obtained.

ELECTRICITY & STEAM:

The use of steam ("central steam") or electricity from external* sources will be effective in reducing sulfur oxide concentrations only if the external source is either remote from the area of concern, or incorporates provisions to reduce its own sulfur oxide emissions below those of the sources it replaces, per unit of energy consumed by the ultimate user. Because electricity can be transmitted over much greater distance than steam, there is more flexibility of location in the case of electric-generating stations. Since many buildings are heated by steam and many processes use steam, the replacement of on-site fuel-burning steam-generating equipment by an external source of steam is usually a fairly simple matter, and may result in reduced labor and maintenance costs to the user.

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*"External" is used to mean outside of the building in which the energy is utilized.

The external generation of either steam or electricity offers possible advantages. Higher efficiencies of steam generation can be achieved with larger units, thereby reducing the fuel burned and the pollutants produced per unit of energy provided. However, electric heating requires more fuel consumption than does direct heating by fuel, and hence may have more air pollution potential. Large installations are more likely to be able to store and shift to the use of an alternate low-sulfur fuel on short notice, thus enhancing the feasibility of "emergency" measures. Finally, the potential for application of gas-cleaning systems is much greater with large installations.

HEAT RECOVERY FROM REFUSE DISPOSAL:

The recovery of waste heat from incineration has several theoretical advantages. If one assumes that incineration must be practiced, and that the incinerator should be located near the source of refuse, then the recovery and utilization of the heat generated could reduce the total quantity of fuel consumed in the area. Recovery of heat from an incineration process serves also to condition the flue gases, permitting more economical and frequently more efficient gas cleaning. Thus, the air pollution potential of refuse incineration, already low with respect to sulfur oxides, may be reduced with respect to particulates and other gases. Of course it costs money to recover this heat, and the first cost of the facility will be substantially increased. The daily variability of the net heat available from refuse collected from a fixed area, and the problems of refuse storage are not wholly compatible with the nature of most steam demands. Conversely, the largely seasonal demands for steam, for heating and air conditioning, are inconsistent with the seasonally stable amounts of refuse generated. Therefore, refuse-burning steam-generation may best be used for "peaking units" in a system which also uses energy from nuclear or fossil fuel. A system for heat rejection, for use during periods of moderate temperature, may also be required.

PRESENT SITUATION IN BOSTON:

Electricity and central steam are already supplying some of the heating requirements in Boston. Over the years, many small heating plants have been set aside in favor of steam from the Boston Edison Company. Many new buildings in the downtown area rely on this form of heat. The central steam- and the electric-generating stations of Boston Edison, all of which (except the Scotia Street Station) normally burn residual oil of about 2.5 percent sulfur content (by weight) are now prepared to shift to low-sulfur oil (of less than one percent sulfur) in the event of adverse meteorological conditions.

These stations are within or close to Boston. All the steam stations (Kneeland Street, Minot Street, Scotia Street) and two of three electric-generating plants (L Street/New Boston, and Mystic Station in Everett) are within the zone of maximum sulfur oxides. The steam plants have quite low stacks. The stacks at the L Street/New Boston Station and two of five stacks at Mystic Station are only 250 feet high. The tallest stacks in the Edison system, 330 feet high, are at the three new units at Mystic Station. (For comparison, consider the 800 and 1200 foot stacks erected at many of the newest large steam-electric stations for the express purpose of dispersing sulfur oxides and particulates.)

Sulfur dioxide emission control equipment is not now available at these Edison stations. Most of the Edison Company steam-electric units are equipped with electro-static precipitators (New Boston, with two 450-mw units is the principal exception). However, none of the precipitators are currently used during oil-firing and, by themselves, would be of negligible value in reducing sulfur dioxide. I understand that the use of these precipitators for collection of particulates during oil-firing is being studied. If this can be done, there is a possibility then of also using a particulate additive for sulfur dioxide control. Of the steam stations, only Kneeland Street is equipped with air pollution control equipment - water scrubbers - and these scrubbers are of low efficiency for removal of sulfur dioxide in their present mode of operation.

DISCUSSION OF ALTERNATIVES:

The full potential for air pollution abatement in Boston by use of external sources of energy is not yet realized. It is regarded as a middle to long-range solution. Substitution of low-sulfur fuels appears to be a much more practical possibility. For many current sources of sulfur dioxide, it is the only means of reducing sulfur dioxide emissions presently feasible. Where coal and residual oil are now used, low-sulfur fuel of the same type may replace it without modification of equipment, if the physical characteristics of the fuel are similar. Potential problems associated with changes in physical characteristics of the oils (low-sulfur residual) are reported by New Jersey authorities not to have been realized. Oil industry spokesmen have confirmed that no significant difficulties should occur.

In Boston, at the present time, only one supplier - White Fuel Company of South Boston - has low-sulfur residual oil available, and only in a limited supply. It is guaranteed to contain less than one percent sulfur and currently contains 0.9%. Derived from Texas crudes, it is of low A.P.I. gravity and pour point, and requires no equipment modification. It appears that this oil is available principally because Boston Edison has arranged to be supplied, on demand, with one percent sulfur oil at its L Street/New Boston, Kneeland and Minot Streets Stations. White Fuel Company has also arranged for a supply of residual oil with a controlled sulfur content of not more than two percent by weight. Neither of these oils, however, is currently available in sufficient quantity to supply the entire Boston market. The bulk of the oil distributed by White Fuel is their "regular, uncontrolled" grade, with sulfur content ranging from 2.2% to 2.6%, by weight. (See Table 9)

Metropolitan Coal and Oil Company of Boston (tank farm in Chelsea), another supplier of fuel oils in the Boston area, and the supplier of coal to the Boston public schools, distributes only one quality of residual fuel oil. It is guaranteed to contain not more than 2.2% sulfur by weight and has recently averaged about 1.9%. Metropolitan indicates that this fuel costs "slightly more than regular" (or high-sulfur) residual oil from other suppliers. This company lacks the facilities to stock more than one grade of residual fuel oil.

Of seven other major oil distributors surveyed, only the Gulf Oil Company, Humble Oil Company, and Union Oil Company stock residual fuel oil. None offers any guarantee of sulfur content. Gulf indicated that their oil contains an average of two percent sulfur, with a range of 1.6% to 2.4%. Humble and Union Oils' products average about 1.6% sulfur, by their statements. In an informal response to a telephone inquiry, no company indicated any plans to stock low-sulfur residual oil. No company anticipated any problems with storage or distribution systems in the event the City of Boston alone limited allowable sulfur content, but the Union Oil Company indicated that a two year lead time would be desirable. They also indicated that the market area served by their Boston terminal extends beyond the metropolitan area and into adjoining states. It is likely that whether the low-sulfur oil were required for Boston alone, for the region, or for the whole state, Union Oil would develop dual storage and distribution capability.

The replacement of residual oil by other fuels of substantially different characteristics is another possibility. Leading candidate fuels are natural gas, either alone or in combination with distillate oil (#2), to be used during periods of maximum gas demand as a reserve fuel. Natural gas is nearly sulfur-free and offers the additional advantages of negligible soot, smoke and ash emissions. Its chief disadvantages are cost and limited availability.

The use of low-priced "seasonally-interruptible" gas, available only during the spring, summer, and fall* reduces sulfur dioxide emissions during that period, and therefore, reduces slightly the average sulfur dioxide concentration for that season and for the year. Its use by utilities, hospitals, laundries, and others during the warm weather would be (and likely is now) of benefit in reducing soot and smoke emissions, and the visibility of plumes. Most users of interruptible gas, as it is currently marketed, burn #5 or #6 oil during the winter season. The Boston Gas Company is now offering a temperature-interruptible "dual-fuel" scheme wherein natural gas is used until the temperature (ambient) drops to a predetermined value, ranging from 40 to 10 degrees Farenheit, at which point, the equipment is automatically shifted from the gas to distillate #2) oil, presently containing 0.25% sulfur by weight. When the ambient temperature subsequently rises above the selected temperature, the use of gas is automatically resumed. Both peak and average sulfur emissions are markedly reduced - compared to the routine burning of #6 oil, or even #2 oil - as are soot and smoke emissions. This system would permit more consumers to use gas during such periods of the heating season when temperatures are "moderate" (above 25 to 30 degrees Farenheit) than would conversion to the use of gas alone, based on present Federal Power Commission allocations. Daytime temperatures associated with extended inversions are likely to be moderate.

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* This gas is sold at prices competitive with residual oil.

The costs of the dual-fuel supply do not appear forbidding. The gas price is intermediate between the prices of interruptible and firm gas supplies, and varies inversely with the temperature selected for the shift to oil. This price would likely range from about $0.50 to less than $1.00 per million BTU. Distillate (#2) oil is currently priced at up to $1.28 per million BTU, (when delivered in small lots to households), as compared to prices for #6 oil, which may be as low as $0.30 per million BTU ($0.41 "posted"). Fuel cost and perhaps equipment cost will increase with the alternative use of low-sulfur residual oil; the prices of gas and #2 fuel oil may also vary with time.

The temporary use of low-sulfur residual oil during periods when adverse weather conditions prevail will markedly reduce sulfur dioxide emissions from those sources which so shift, during those periods. For such conversion to be possible, the source must have or create standby storage (i.e., an extra tank) for the low-sulfur oil sufficient for a demand of at least three to four days. Provision must be made for maintaining that oil in the proper condition for burning or for rapid conditioning. The standby oil should be consumed prior to the end of the heating season so that a fresh supply may be acquired for the next year. The regular and standby oils should be of comparable gravity, viscosity, pour and flow points. It is doubtful that many of the current users of residual oil (in categories such as apartment houses, commercial, institutional and small industrial) would be capable of adopting such a program without extensive modifications to their facilities. Earlier I noted that Boston Edison has established the capacity to and on occasion has temporarily shifted to low-sulfur residual oil (of less than one percent) when adverse atmospheric conditions prevailed. Other establishments, notably large institutions, have made similar provisions. For this system to be continued as an exception, to a more general requirement for reduction of emissions of sulfur oxides, demands proof of its merits from its proponents. Adverse effects of sea-breezes and of the break-up of stable atmospheres must be considered. Air quality goals must be achieved without placing additional burdens on other sectors of the economy. Techniques for developing and testing programs for achieving "least-cost" solutions to the problem of achieving some set of air quality goals are being studied. However, we presently lack much of the required data and proven techniques.

It has been suggested that the effects of adverse atmospheric conditions might be mitigated by other temporary measures. One, source-oriented, would be to request or require a fuel consumption reduction (work slow-down, reduction of thermostat setting, etc.). I regard any reliance on voluntary cooperation as unwise and any attempt at enforcement as impractical. Another, receptor-oriented, would be to request or require "susceptible" persons to either remain in, or go to "areas of low exposure potential". Several problems are forseen. The definitions of such "susceptible" persons or "areas of low exposure potential" may be difficult to establish and to project to the public. Achievement of compliance with the instruction and measurement of achievement are likely to be impossible. The question of whether the urban atmosphere is to be safe at all times only for some people is equally important. Concern has already been expressed over implications of making some people "second-class citizens" by the establishment of air quality standards which vary with land use or location. Thus, neither suggestion is a feasible alternative to reducing emissions of sulfur dioxide.

TABLE 4

WHITE FUEL COMPANY - RESIDUAL OIL STOCK - 1969

GRADE OF OIL (#6)	% SULFUR CONTENT (by weight)	POSTED TANK CAR PRICE (per bbl.)	POSTED PRICE INCREASE $/bbl.	$/gal.	%
Regular, uncontrolled	2.2% - 2.6%	$2.39*	-	-	-
Regular, controlled	2.0% Maximum	$2.46	$0.10	$0.003	4%
Low-gravity, low-sulfur	1.0%Maximum	$2.60**	$0.21***	$0.007	9%

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* The City of Boston buys this oil under contract at the "discounted" price of about $1.88 per barrel. The Boston Edison Company pays $1.75 per barrel.

** This corresponds closely to the New York City price. It is doubtful that substantial discounting will occur, though at present, the Boston Edison Company pays about $2.25 per barrel.

*** At $1.88 per barrel for "regular" #6 oil, and assuming no discounting of the low-sulfur oil, the price increase might be as high as $0.82 per barrel, or an increase of 43%. Some discounting is expected.

CONCLUSIONS

Reduction of sulfur in fuels would reduce the exposure of population groups, vegetation, and materials to sulfur oxides. The objectionable appearance of plumes from certain large sources would be improved. Haze would be reduced. The arguments for control are buttressed by an apparent relationship between health and the presence of atmospheric sulfur dioxide (in associaiton with other conditions); by well-documented evidence of sulfur dioxide damage to vegetation; by significant qualitative and quantitative evidence of the effect of contaminated atmospheres on materials; and by theoretical estimates of the reductions in visibility which could be associated with increasing concentrations of sulfur oxides in the atmosphere.

I have previously expressed to the Commission, as my opinion, that the atmosphere in Boston is not as clean as it could be or should be, and that we must make every effort to improve it. In this report, I have discussed the nature of the evidence indicting sulfur oxides. This evidence does, in my opinion, justify measures to reduce emissions of sulfur oxides.

The issue is not "whether control". I am satisfied and I believe the Commission is satisfied that air quality should be improved by reducing the concentration of sulfur oxides. The issue is not primarily one of identifying a satisfactory quality for air, although this should be done. Air quality goals have been considered by the Commission and are being studied by an ad-hoc committee advisory to Dr. Alfred L. Frechette, Commissioner of the Department of Public Health, Commonwealth of Massachusetts. The Commission will be guided by the report of the ad-hoc committee to Dr. Frechette, and also by evidence introduced at the forthcoming hearing on air quality standards, to be conducted by his department. In the meantime, for guidance of its staff, the Commission has suggested a tentative goal for sulfur oxides, as shown below.

"The United States DHEW has urged that the available data on effects of air pollution be regarded conservatively, and that a "factor of safety" be applied. "*

AIR QUALITY IN BOSTON

SULFUR DIOXIDE

Condition	Annual Mean Concentration		Maximum 3-Day Average Concentration	
	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)	(ppm)
Observed air quality in Central Boston - 1966:	170	.06	460	.16
U.S.D.H.E.W. "adverse health effects" level:	115	.04	290	.11
(Factor of safety suggested by Commission)	(2)		(2)	
Suggested air quality goal:	50-60	.02	150	.05

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* United States Department of Health, Education, and Welfare, Air Quality Criteria for Sulfur Oxides, page 10:22.

The suggested Commission goal of 0.02 ppm sulfur dioxide (annual average) would require a three-fold reduction in average annual concentrations. If no increases in energy consumption in the area were to occur in the near future, and no shift in fuel use patterns is assumed, a three-fold reduction in (1966) source strength would be required.

In the Boston urban area, the principal source of atmospheric sulfur oxides is the burning of sulfur-containing fossil fuels. Given the present state of control technology, it is apparent that the only currently practical control techniques are the reduction of emission potential by the temporary or permanent substitution of low-sulfur fuels, and the use of energy from external sources. Thus residual fuel oil containing about three-quarters of one percent sulfur by weight would be appropriate, given the current two to two-and-one-half percent sulfur content of most residual fuel oil. Both growth and shifts in fuel use patterns will occur in the near future, but the net effect on required fossil fuel quality is not known. An optimistic view might be that the two factors will balance.

Two main issues prompted this report. The first, should sulfur in fuels be reduced, has been affirmatively discussed above. The second issue, whether the City of Boston should independently seek to reduce sulfur in fuels to a stated level at this time is discussed below.

Legally, the move is feasible. The regulation of fuel oil quality is within the power of the Commission, provided the

Department of Public Health (Massachusetts) would approve. Emission standards would probably have to be incorporated and provisions made for exceptions. I believe that the Boston Edison Company would probably challenge as unreasonable or unnecessary a requirement that all of their units burn low-sulfur fuel at all times. Edison believes it can demonstrate that emissions from their steam-electric (L Street and New Boston, in Boston) do not significantly affect ambient ground-level concentrations of sulfur dioxide much of the time. This challenge would likely be made regardless of the level of government proposing the regulation.

Technically, the move is feasible. Sufficient stocks of residual oil containing less than one percent are now available, although commitments for this area must be increased and facilities for storage and distribution will have to be altered or increased. It seems unreasonable to seek to implement such a change during this heating season, because of the above, and in consideration of existing contracts. The additional storage capacity and changes in distribution systems required of the terminal operators cannot be provided immediately, to the scale required. A lead time of one year is needed; the operators might press for two years. The oil would be compatible with existing equipment, in most if not all instances.

Economically, the move is feasible. The estimated cost of conversion to low-sulfur fuel oil is tabulated on the next page for various categories of current users of residual oil. No change in use patterns is presumed. Unit cost differentials are estimated for each category. These estimates are based on current discounting of regular residual oil ranging upwards to 25% of posted price and assume only limited discounting of low-sulfur oil, and only to large contract purchasers.

ESTIMATED COST OF CONVERSION TO LOW-SULFUR OIL ***

(Boston only)

User	Use (10^6 bbls.)	Increased Cost ($/bbl.)	($/year)
City of Boston buildings	1.0*	$0.56	$400,000*
Commercial Institutional Residential	6.2*	$0.65	$3,000,000*
Industrial	2.0	$0.63	$1,300,000
Utility	7.0	$0.50	$3,500,000**
		TOTAL	$8,200,000

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* #5 oil at about 1.8% sulfur is a significant portion of this use, and the price increase for low-sulfur is expected to be less for the #5 grade than for #6 oil. Nevertheless, estimates are based on #6 oil.

** Actual expenditure for intermittent use during the first half of 1969 was about $250,000.

I estimate total current expenditure for fuel in Boston, for all fuels, by all users, to be about $100,000,000 per year. Thus the increased cost of low-sulfur oil would be less than ten percent of the total annual fuel bill. Some portion of the increased costs borne by commercial and institutional users, and by utilities would be passed on to consumers and taxpayers outside of Boston, since the increased costs of goods and services that will result will be spread uniformly among those who buy the goods and services. The slightly increased cost of living and of doing business in Boston would materially reduce the impact of air pollution. Corrosion of buildings, machinery, art objects, and other materials, damage to clothing, furnishings and other fabrics would be greatly reduced. Most importantly, the threat of further and future damage to the health of persons in Boston, due to air pollution, would also be greatly reduced.

*** For a further breakdown of these facts, see Table A-3 in the Appendix.

The administration and enforcement of a unilateral regulatory program to limit sulfur in classes of fuels consumed in Boston would require additional staff for inspection and would involve sampling and analysis of fuels, as used, or as stored for use. Regulation of importation, storage, or transportation of fuels would be impractical since fuels move through Boston for other, presumably legal uses. The program would cost about $25,000 per year plus costs of prosecution. I believe the move to be administratively feasible, but far less desirable than regulation and control, by the State, of sulfur content in fuels used within the Metropolitan Air Pollution Control District or the Boston Air Quality Control Region.

RECOMMENDATIONS

I recommend as an objective for residual fuel oil quality, that such fuels contain less than one percent sulfur by weight. This objective should be achieved by the 1970-71 heating season. I further recommend an active program to increase acceptance of the "dual-fuel" system and central steam, and to prepare fuel users and the fuel industry for the change to low-sulfur fuel. Equivalent restrictions should be formally imposed on the sulfur content of coals, to insure that coal of appropriate quality continues to be supplied.

I see no point in a step-wise program of reduction of sulfur levels to, say, less than two percent in 1970-71, and less than one percent in 1971-72.

I further suggest that this report be presented to the Mayor, the City Council, and to other interested parties for information and comment. Favorable reaction should be construed as support for such action by the Massachusetts Department of Public Health. I believe that Department desires to implement a similar program of sulfur oxide control throughout the Boston Air Quality Control Region on a similar timetable. It would therefore be most helpful to present this report at or before its hearing on air quality standards.

If substantially less stringent action, or a later implementation date is selected by the Department for submittal through the Governor to the Department of Health, Education and Welfare, then I will request the Commission consider immediate adoption of an appropriate regulatory program.

APPENDIX

TABLE - A-1

CITY OF BOSTON FUEL USE

Fuel	Sulfur Content*	Consumption		Sulfur Dioxide Emitted (tons
		Fuel (gal.)	Sulfur (tons)	
BOSTON PUBLIC SCHOOLS:				
#2 oil	0.25%	11,550,000	120	240
#5 oil	1.8%	5,880,000	440	880
Coal	0.65%	9,440 tons	120	240
TOTAL:	17,430,000 gallons oil 9,440 tons coal			
		680 tons of sulfur consumed 1360 tons of sulfur dioxide emitted		
BOSTON HOUSING AUTHORITY:				
#6 oil	2.5%	16,377,774	1650	3,300
HEALTH & HOSPITALS:				
Boston City Hospital				
#6 oil	2.75%	3,519,653	400	800
Long Island Hospital				
#2 oil	1.8%	13,438	.14	.28
#6 oil	2.5%	824,775	85	170
TOTAL:	4,357,865 gallons oil			
		485 tons of sulfur consumed 970 tons of sulfur dioxide emitted		
PENAL DIVISION - DEER ISLAND:				
#6 oil	2.5%	781,001	220	440

* Estimated sulfur content of different grades of fuel; with the exception of Boston City Hospital and the Boston Public Schools (coal) for which percentages were available.

Fuel	Sulfur Content	Consumption Fuel (gal.)	Consumption Sulfur (tons)	Sulfur Dioxide Emitted (tons)
PARKS DEPARTMENT:				
#2 oil	.25%	394,570	2	4
#5 oil	1.8 %	163,941	130	260
TOTAL:	558,511 gallons oil 129 tons of sulfur consumed 249 tons of sulfur dioxide emitted			
FIRE DEPARTMENT:				
#2 oil	.25%	542,444	5.5	11
#5 oil	1.8%	9,300	4.7	9.4
#6 oil	2.5 %	132,407	14	28
TOTAL:	684,151 gallons of oil 24 tons of sulfur consumed 48 tons of sulfur dioxide emitted			
CEMETERY DIVISION:				
#2 oil	.25%	14,810	.16	.32
Coal	1.25%	9,000 lbs.	.06	.12
TOTAL:	14,810 gallons oil 9,000 pounds coal .22 tons of sulfur consumed .43 tons of sulfur dioxide emitted			

TABLE - A-2

CITY OF BOSTON FACILITIES

Though consumption figures for the following have not as yet been obtained, in most cases, the type of fuel used is noted.

New City Hall	Purchased steam
Old City Hall	Purchased steam
Old State House	#2 oil
Faneuil Hall	#2 oil
Quincy Market	#2 oil
Courthouses - 6	#2 oil
Little City Halls - 4	#2 oil
2	#5 oil
1	Gas
3	Trailers
Printing Office	#5 oil
Civil Defense	Kerosene, Gas, #2 oil
Mattapan Hospital	#6 oil
Hospital Health Units - 4	#5 oil
5	#2 oil
Welfare Department - 30	#2 oil
1	#2 oil and #5 oil
Police Department - 14	#2 oil
1	#5 oil
Headquarters	Steam
Suffolk Jail	Coal - to be converted to gas
Library Department - 29	#2 oil
1	#5 oil
Public Works Department	No data available

TABLE A-3

RESIDUAL (#6) FUEL OIL PRICE STRUCTURE

Boston Market - Fall of 1969

Price Basis	Grade of Oil						Cost Increase for Low-Sulfur #6 Oil	
	"Regular" (Uncontrolled Sulfur Content)			"Low-Sulfur" (≤ 1%)			$/bbl.	% (approx.)
	Posted Price	Discount (%)	Net Cost	Posted Price	Discount (%)	Net Cost		
EDISON: (contract)	$2.39	$0.64 (27%)	$1.75	$2.60	$0.35 (14%)	$2.25	$0.50	30%
CITY OF BOSTON: (contract)	$2.39	$0.51 (21%)	$1.88	$2.60	$0.16 (14%)	$2.44**	$0.56**	30%

* Net costs are in dollars per 42-gallon barrels, $/bbl.
Discounts are in $/bbl. and percentage, from posted price of that grade.

**Estimate based on preceeding data in this table.